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April 1958

Silvical Characteristics of Engelmann Spruce

by

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ROCKY MOUNTAIN
FOREST AND RANGE
EXPERIMENT STATION
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Fort Collins, Colorado

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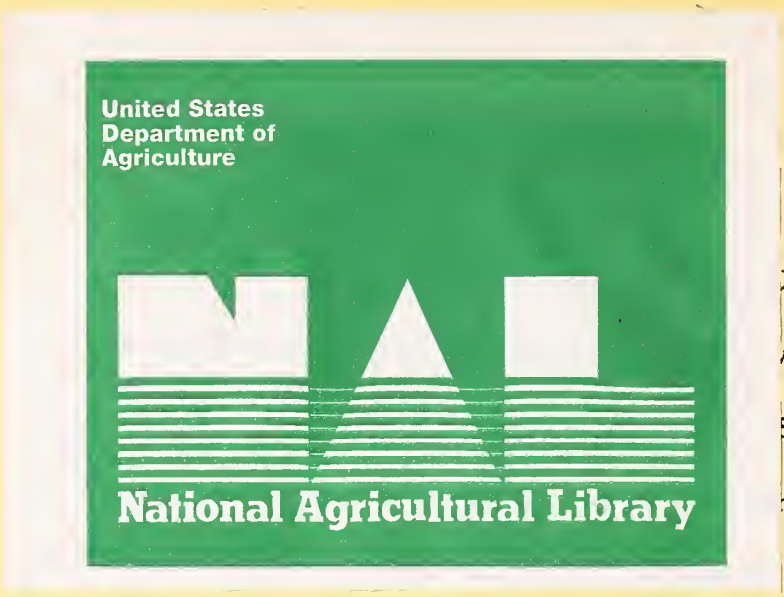

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compile this material systematically and make it available to foresters generally, the Rocky Mountain Forest and Range Experiment Station is preparing reports on 4 individual tree species. Similar reports on other species are being prepared by other Forest Service experiment stations. A comprehensive national publication containing the silvical characteristics of all important forest trees of the United States will be issued soon by the Forest Service, U. S. Department of Agriculture.

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Cover Photo: Mature Engelmann spruce,
Fraser Experimental Forest, Colorado.

Station Paper No. 31 April 1958

SILVICAL CHARACTERISTICS OF ENGELMANN SPRUCE

by

R. R. Alexander, Forester

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE

The station maintains central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University.

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SILVICAL CHARACTERISTICS OF ENGELMANN SPRUCE

by

R. R. Alexander

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Engelmann spruce (Picea engelmannii Parry) is one of six species of spruce indigenous to the western United States. Other common names include Columbian spruce, mountain spruce, silver spruce, and white spruce (20).

DISTRIBUTION

Engelmann spruce is widely distributed; extensive stands are found in nine western States and two Canadian provinces. Its range extends from British Columbia and Alberta, south to New Mexico and Arizona (fig. 1).

In the Pacific Coast region, Engelmann spruce occurs along the east slope of the Coast Range from west central British Columbia, south along the east slope of the Cascades through Washington and Oregon to Mount Shasta in northern California (23). It is only a minor component of the high-elevation forests near the Pacific Coast.

Engelmann spruce is found in the Rocky Mountains of southwestern Alberta, south through the high mountains of northeastern Washington, northern and eastern Idaho, western Montana, northeastern Oregon, to western and central Wyoming; and in the high mountains of southern Wyoming, Colorado, northern and southwestern New Mexico, central Arizona, and Utah (23). It is a major component of the high-elevation forests of the Rocky Mountain region.

BOTANICAL DESCRIPTION (26)

Needles. -- The petioled, flexible, 4-angled needles average 1 to 1-1/8 inches long, with blunt or acute tips. They are blue green with an occasional whitish, glaucous bloom. Needles tend to be crowded on the upper side of the branch because those on the lower side curve upwards (fig. 2).

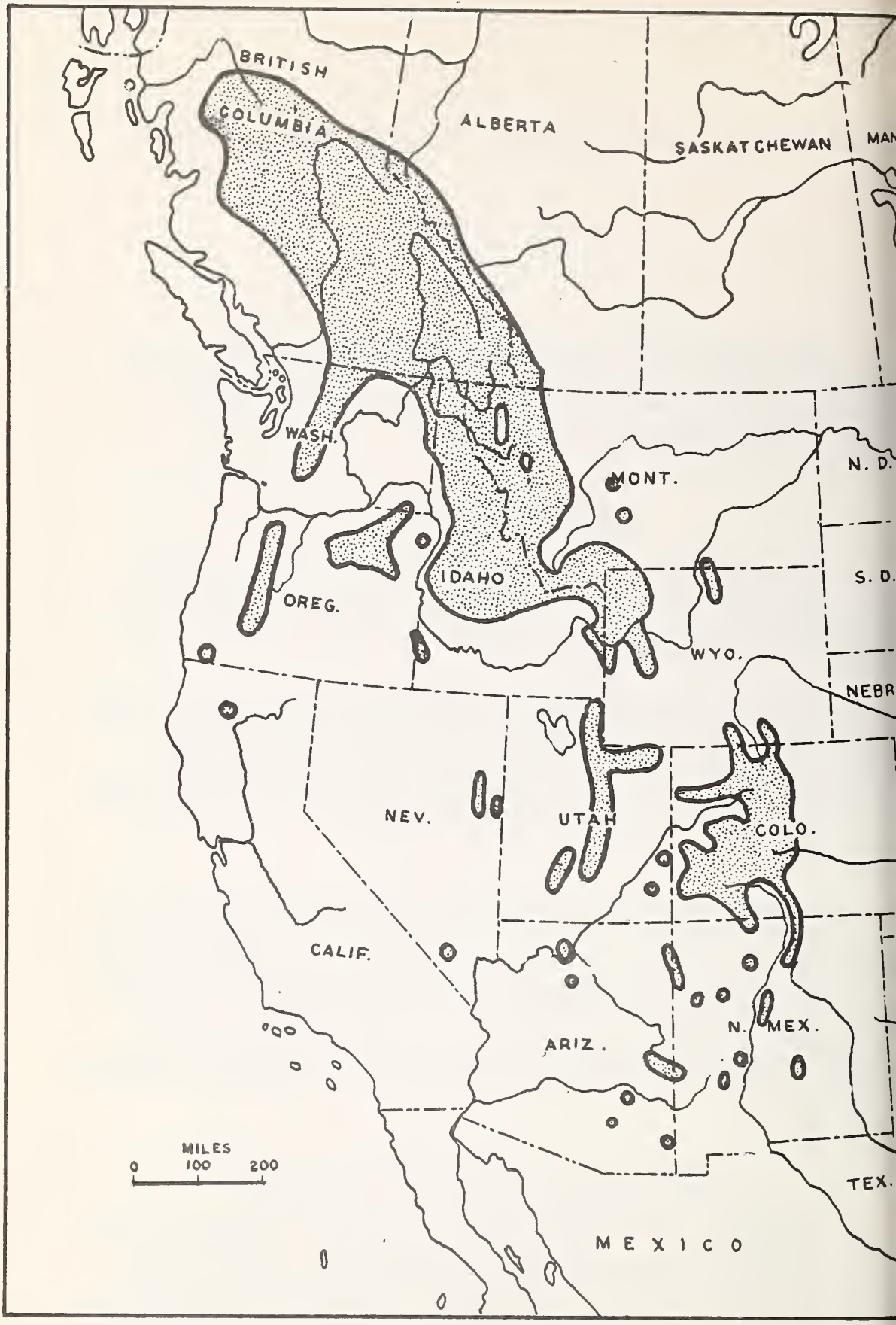

Figure 1.--Natural range of Engelmann spruce.

Figure 2. --Cones and needles of Engelmann spruce.

Flowers. --Male flowers are dark purple; female, bright scarlet.

Cones. --The light-chestnut brown, ovate to cylindrical cones average 1 to 2-1/2 inches long. They are sessile or short stalked with flexible scales that are variable in outline and erose-dentate at the apex (fig. 2). Cones are shed during the fall or winter of the first year. The nearly black seed average 1/8 inch long, with a broad, oblique wing.

Twigs. --Minutely pubescent, rather stout and orange brown to gray brown. Winter buds are pale chestnut brown, broadly ovoid to conic, and average 1/8 to 1/4 inch long.

Bark. --Thin, cinnamon red to purple brown; broken into large, thin, loosely attached scales.

Wood. --Heartwood is creamy white with a light reddish brown or light yellowish tinge. Sapwood is light, creamy colored, and difficult to distinguish from heartwood except for the reddish tinge of the latter.

Wood is straight grained, light weight, medium stiff, soft, fine textured, and without odor or taste. Resin ducts are few, but distinguish the wood from the true firs.

HABITAT CONDITIONS

CLIMATIC

Engelmann spruce grows in a climatic zone classified as cold and humid (38). It occupies the highest and coldest forest environment in the western United States. The climate is characterized by annual temperature extremes of more than 50° F. below zero to more than 90° F. above, and heavy snowfall. Climatic data for four subdivisions of the species range are given below (3).

Table 1. --Climatological data for four subdivisions within the range of Engelmann spruce

Location	Average temperature			Annual precipitation	Annual snowfall	Frost-free period
	Annual	July	January			
	- - - °F. - - -			- - Inches - -		Days
Pacific Coast	35	50-55	15-20	60-160	400+	45-90
Rocky Mountains:						
Northern	30-35	45-55	10-20	45+	250+	[1] 0-60
Central	30-35	50-55	10-15	25-35	150-350	[1] 0-60
Southern	35	50-60	15-20	25-35	200+	[1] 0-75

[1] Frost may occur any month of the year.

The range of mean annual temperatures is narrow, considering the wide distribution of the species. Average annual temperatures are near freezing; summer temperatures average 45° to 60° F., and winter temperatures 10° to 20° F. (3).

Average precipitation exceeds 25 inches annually, with only moderate or no seasonal deficiency. Summer is the driest season in the Cascades and Rocky Mountains west of the Continental Divide as far south as southern Colorado. East of the divide and in the mountains of southern Colorado, New Mexico, Arizona, and southern Utah, late-summer rainfall is heavy and winter snowfall relatively light (3, 38).

EDAPHIC

Information on the soils on which Engelmann spruce grows is limited. In the northern Rocky Mountains, soils are generally young, and well-defined profiles are rare. However, some of the deepest soils with the best defined profiles found in the central Rocky Mountains are growing spruce.

It makes its best growth on moderately deep, well-drained silt and clay loam soils developed from basalt, andesite, rhyolite, shale, and limestone. Good growth is also made on alluvial soils, developed from a wide range of parent materials, where an accessible water table is more important than physical properties of the soil.

Engelmann spruce does not make good growth on shallow, dry, coarse-textured sands and gravels developed primarily from granitic and schistic rock, and coarse sandstones; heavy clay surface soils; or saturated soils.

PHYSIOGRAPHIC

Along the east slope of the Coast Range and interior valleys of southwestern British Columbia, Engelmann spruce grows at 2,500 to 3,500 feet. Farther south in the Cascade Mountains of Washington and Oregon, it generally grows at 4,000 to 6,000 feet but may be found at 8,000 feet on sheltered slopes and at 2,000 feet in cold pockets along streams and valley bottoms; in northern California, at 4,000 to 5,000 feet (15, 36).

South of the Peace River Plateau in the Rocky Mountains of British Columbia and Alberta, Engelmann spruce grows at 2,500 to 6,000 feet; in the northern Rocky Mountains, at 2,000 to 11,000 feet. But above 6,000 to 7,500 feet, it is a minor component of the stand, and below 5,000 feet it is confined to moist lower slopes and cold valley bottoms (16, 17).

Engelmann spruce is found at 9,000 to 11,000 feet in the central Rocky Mountains, but it may extend as low as 8,000 feet along cold stream bottoms and to timberline at 11,500 feet. In the southern Rocky Mountains it grows at 9,500 to 11,000 feet but may grow as low as 8,000 feet and as high as 12,000 feet (7, 25).

BIOTIC

Engelmann spruce is most typically found in mixture with subalpine fir to form a relatively uniform type[1/] (33). It is also found in 14 other cover types; however, it either forms a minor component or occupies cold pockets within the types. In the cold pockets, it is often accompanied by subalpine fir (Abies lasiocarpa (Hook.) Nutt.) and constitutes, in effect, an isolated island of the Engelmann spruce-subalpine fir type. Types in which it is associated include white spruce, poplar-birch, mountain hemlock-subalpine fir, whitebark pine, bristlecone pine, interior Douglas-fir, western larch-interior Douglas-fir, grand fir-western larch-interior Douglas-fir, western white pine, blue spruce, aspen, lodgepole pine, western redcedar-western hemlock, and western redcedar (33).

The composition of the forest in which Engelmann spruce grows is influenced by elevation, exposure, and latitude. In the Rocky Mountains and Cascades, subalpine fir is its common associate at all elevations. In Alberta, it mixes with white spruce (Picea glauca (Moench) Voss), western white spruce (Picea glauca var. albertiana (S. Brown) Sarg.), balsam poplar (Populus balsamifera L.), and birch (Betula spp.). In the northern Rocky Mountains, associates at lower elevations include western white pine (Pinus monticola Dougl.), western redcedar (Thuja plicata Donn), and western hemlock (Tsuga heterophylla (Raf.) Sarg.); at middle elevations interior Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco), western larch (Larix occidentalis Nutt.), lodgepole pine (Pinus contorta Dougl.), and grand fir (Abies grandis (Dougl.) Lindl.); and at higher elevations mountain hemlock (Tsuga mertensiana (Bong.) Carr.), whitebark pine (Pinus albicaulis Engelm.), and subalpine larch (Larix lyallii Parl.). Engelmann spruce extends to timberline in some places; in others, its high-elevation associates form the timberline forests (16, 17).

1/ The Engelmann spruce-subalpine fir forest type is considered by some ecologists to be the western mountains' counterpart of the boreal spruce-fir association of the East and far North.

In the central Rocky Mountains, lodgepole pine, interior Douglas-fir, blue spruce (Picea pungens Engelm.), and aspen (Populus tremuloides Michx.) are associates at lower elevations; and whitebark pine, bristlecone pine (Pinus aristata Engelm.), and limber pine (Pinus flexilis James) at middle and higher elevations. In association with subalpine fir, it forms the timberline forest.

In the southern Rocky Mountains, white fir (Abies concolor (Gord. & Glend.) Lindl.), interior Douglas-fir, blue spruce, aspen, and occasionally ponderosa pine (Pinus ponderosa Laws.) are associates at lower elevations; and corkbark fir (Abies lasiocarpa var. arizonica (Merriam) Lemm.), and bristlecone pine at middle and higher elevations. It extends above corkbark and subalpine fir, forming nearly pure stands at timberline (19, 25).

In the Cascades, it mixes with western white pine, western larch, grand fir, western hemlock, western redcedar, and Pacific silver fir (Abies amabilis (Dougl.) Forbes) at lower elevations; and subalpine larch, mountain hemlock, lodgepole pine, and whitebark pine at higher elevations. It rarely extends to timberline; subalpine fir, mountain hemlock, and whitebark pine form the timberline forests.

Throughout its range, Engelmann spruce is more abundant on the cooler, moister north and east slopes at low and middle elevations, but it occurs on all slopes at higher elevations.

Common shrub associates include, in northern Rockies: grouse whortleberry (Vaccinium scoparium Leiberg), big whortleberry (V. membranaceum Dougl.), ovalleaf whortleberry (V. ovalifolium Smith), rusty skunkbush (Menziesia ferruginea Smith), alder (Alnus spp.), Pacific yew (Taxus brevifolia Nutt.), elderberry (Sambucus spp.), devilsclub Oplopanax horridus (Smith) Dec. & Planck); in central Rockies: grouse whortleberry, prickly currant (Ribes lacustre (Pers.) Poir.), and russet buffaloberry (Shepherdia canadensis (L.) Nutt.); in southern Rockies: common juniper (Juniperus communis L.) and creeping mahonia (Mahonia repens (Lindl.) G. Don); and in Cascades: big whortleberry, myrtle boxleaf (Pachistima myrsinites (Pursh.) Raf.), false azalea (Azaleastrum albiflorum (Hook.) Rydg.), beargrass (Xerophyllum tenax (Pursh.) Nutt.), and smooth Labrador tea (Ledum glandulosum Nutt.) (18, 24, 32). None of these are known to be indicator plants.

LIFE HISTORY

SEEDING HABITS

Flowering and fruiting

Male and female flowers are borne separately on the same tree. Male flowers ripen and pollen is wind disseminated in June at lower elevations and in July at higher elevations. Cones mature in late August and September of the first year. Seeds ripen late in September or early in October (39).

The effect of climatic and biotic factors on flowering and fruiting is not known.

Seed production

Engelmann spruce begins bearing cones between the ages of 16 and 25 years (39). The maximum amount of seed is produced by dominant trees that average 18 to 30 inches in diameter and are between 200 and 250 years old (13, 24, 39).

Engelmann spruce is rated a moderate to good seed producer (11, 39). Good crops are generally borne every 2 to 6 years, with light crops in more than half of the intervening years (18, 21, 39).

One study in Montana, covering 22 seasons over a 45-year period, rated Engelmann spruce a good to prolific seeder west of the Continental Divide on the basis of 1 to 7 consecutive good crops followed by 1 to 5 poor crops. But, east of the divide, spruce was rated only fair, for 2 to 3 consecutive good crops were followed by 2 to 5 poor crops (11).

Some loss of seed results from the cutting and storing of cones by the Fremont chickaree (Tamaisciurus fremonti Audubon & Bachman) and the western chipmunk (Eutamias minimus Bachman), but the actual quantitative loss is not known. Mice and other small rodents are known to eat the shed seed, but apparently the small seeds are easily missed by the rodents and a large proportion escapes them. Studies in Montana have shown that seedling success on protected seed spots is little better than on unprotected spots (31).

Seed dissemination

Cones begin to open in September. Most of the seed is shed by the end of October, but some falls throughout the winter. The small seeds average about 135,000 per pound (39). Practically all of the seed is disseminated by wind. The storing of cones by squirrels and rodents plays only a minor part in seed dissemination.

Seed is dispersed one-eighth mile or more by the wind. In one study during a bumper seed year, an average of 60,000 seeds per acre were blown this far into a clearcut area. Seedfall in the adjacent uncut stand averaged 950,000 seeds per acre (34). In an average good year, 3 to 4 bushels of cones per acre, averaging 190,000 seeds per bushel, can be expected (21). However, the number of viable seeds required to produce a single seedling is not known.

VEGETATIVE REPRODUCTION

Engelmann spruce can reproduce by layering (13). It often layers near timberline where the species assumes a characteristic dwarfed or prostrate form. But this method of reproduction is insignificant in the establishment and maintenance of closed forest stands (24).

SEEDLING DEVELOPMENT

Germination and establishment

Viability of Engelmann spruce seed is rated good and the vitality persistent, as much as 30 to 50 percent germination after 5 years when properly stored (40). The average rate of germination is higher than that of associated species, as is shown in the following tabulation (38):

Species	Average percent of germination	Species	Average percent of germination
Engelmann spruce	69	Western larch	27
Subalpine fir	38	Grand fir	28
Lodgepole pine	64	Western hemlock	56
Western white pine	54	Pacific silver fir	24

In nature, Engelmann spruce seed lies dormant overwinter and germinates the following spring. In common with most species, it germinates more readily on mineral soil than on the undisturbed forest floor (10, 21, 28, 32). Under natural conditions, Engelmann spruce seedlings become established on mounds of earth near upturned trees, on decaying stumps and moss-covered logs, on landslide areas on steep slopes, and under a cover of Vaccinium spp. on light, gravelly soils (18, 24, 35). Once established, the seedling's ability to survive is not increased by a mineral seedbed but is favored by adequate soil moisture, cool temperatures, and less than 50 percent full sunlight (10).

Bates (6) found that, on most soils studied, spruce seedlings could deplete the moisture to a greater extent than such associates as interior Douglas-fir and lodgepole pine. He also found that spruce tolerates a great moisture loss and a high concentration of cell sap in the needles without permanent injury. These abilities to reduce soil moisture to a low level and to resist transpiration losses makes Engelmann spruce one of the least moisture-demanding trees of the Rocky Mountain region. In Bates' opinion, high sap density enables it to endure cool, high-elevation sites where winter drought may be severe. It is more resistant to winterkilling and frost injury than interior Douglas-fir, lodgepole pine, ponderosa pine, western white pine, and bristlecone pine; but it is not more so than subalpine fir, limber pine, and whitebark pine (6).

However, Engelmann spruce is no more resistant to summer drought than its associates; and because of its slow feeble rooting habit and extreme sensitivity to heat in the seedling stage, it has pronounced limitations in adjusting to high temperatures, even when soil moisture is available (6).

Although comparatively deep shade improves early survival, Engelmann spruce will germinate and become established in all intensities of light found in nature (5). It can make better use of low light intensities than either lodgepole pine, interior Douglas-fir, or western white pine (8); but when grown with more shade-enduring species, such as subalpine fir, the net effect of deep shade favors the fir.

Engelmann spruce seedlings can withstand exposure to strong light better than subalpine fir, but not so well as lodgepole pine. After three growing seasons in one study, the stocking of spruce exceeded fir in light intensities ranging from full sunlight to about 50 percent of sunlight. The stocking of lodgepole pine exceeded

spruce in light intensities down to 40 percent of full sunlight, the lowest intensity studied (28).

Drought, heat, cutworms, frost-heaving, damping-off, rabbits and other rodents kill Engelmann spruce seedlings, but losses are no greater than those of any associate.

Early growth

The early growth of Engelmann spruce is slow (18). In one test, roots of the most vigorous seedlings penetrated less than 3 inches in an undisturbed seedbed in 1 year (30). Penetration was not much deeper in mineral soil. Observations in the northern Rockies indicate that first-year root penetration averages about 1-1/2 inches.

Shoot growth is equally slow. In one test, 5-year-old seedlings averaged less than 1 inch in height under natural conditions, 2 inches in a clear cutting, and from 2 to 3 inches in a partial cutting. At the end of 7 years, seedlings under natural conditions had grown only 1 inch; those left after clear cutting, 3 to 4 inches; and those left after partial cutting, 2 to 4 inches (30).

In a closed forest, Engelmann spruce 4 to 6 feet tall were found to be 45 to 75 years old. Subalpine fir in the same height range were 35 to 50 years old (24).

SAPLING STAGE TO MATURITY

Growth and yield

Engelmann spruce is one of the largest of the high-mountain species. Under favorable conditions, it will average 18 to 30 inches in diameter and 80 to 100 feet in height (12, 13). Larger, mature dominants may exceed 40 inches in diameter and average 150 to 160 feet in height (12, 18). The largest one on record is 19 feet 11 inches in circumference at breast height, 104 feet high, with a 30-foot crown spread (1). It is a long-lived tree, maturing in about 300 years. Trees 16 to 22 inches in diameter are often 350 to 450 years old, and trees older than 500 years are not uncommon (12). Bates (9) reported one tree with 660 annual rings.

Engelmann spruce has the capacity to make good growth at advanced ages. If given sufficient growing space, it will continue to grow steadily in diameter for 300 years. By comparison, the growth of western white pine slows down at 100 to 120 years; interior Douglas-fir, at about 100 years; western larch, at less than 100 years; and lodgepole pine, at 50 to 80 years. Subalpine fir does not retain the capacity for growth at advanced ages, but it will outgrow Engelmann spruce during the early years (18).

Yields are usually expressed for the total stand. Engelmann spruce does not normally grow in pure stands but in varying mixtures with associated species. Average volumes per acre in old-growth spruce-fir may be practically nothing at timberline, 5,000 to 15,000 board-feet on poor sites, and 25,000 to 40,000 board-feet on better sites. Volumes as high as 80,000 to 100,000 board-feet have been reported (25, 27, 37). Average annual growth in virgin spruce-fir forests will vary from less than nothing (a loss) to more than 300 board-feet per acre, depending upon the age, density, and vigor of the stand.

Frequently the structure of old-growth Engelmann spruce-subalpine fir forests is nearly pure spruce in the overstory with fir predominating in the understory. In old-growth spruce-fir forests in southern Wyoming, Engelmann spruce never made up less than 70 percent of the total basal area and often made up more than 90 percent (24).

Competition and natural enemies

Engelmann spruce is rated tolerant in its ability to endure shade. It is definitely more shade enduring than interior Douglas-fir, western white pine, lodgepole pine, western larch, or ponderosa pine but less so than subalpine fir, the most common associate throughout much of its range (4).

The Engelmann spruce-subalpine fir type forms a stable or near-climax forest vegetation throughout much of the area it occupies. Many spruce-fir forests differ from true climax forests in that they are not all-aged. Some ecologists believe the comparative scarcity of all-aged stands may be due to catastrophic fires that preceded the establishment of the mature spruce forests now growing in the Rocky Mountains. Stands are usually even-aged, two-aged, or broad-aged (18).

When a climax forest is destroyed and replaced by other forest trees, the natural tendency is for it to return gradually to climax (18). On northerly exposures, Engelmann spruce and subalpine fir usually return at once. On southerly exposures, such species as aspen, interior Douglas-fir, lodgepole pine, and western white pine become established initially, but they are eventually replaced by the more shade-tolerant spruce and fir (18, 25). Engelmann spruce may be suppressed under the latter conditions or in dense virgin stands for 50 to 100 years, but it will respond quickly to release and soon outgrow its common associates (12, 13).

Engelmann spruce is susceptible to windthrow, especially after partial cutting (fig. 3). This tendency is attributed to a shallow root system. Where trees grow on bogs or in soils underlain by impervious rock or clay subsoils, a weak, superficial root system common to the seedling stage may persist to old age. But when spruce grows on deep, porous soils, the lateral root system may penetrate deeper than 8 feet.

Figure 3.--Windthrown Engelmann spruce, Fraser Experimental Forest, Colorado.

Old-growth Engelmann spruce is especially susceptible to devastating attacks by the spruce bark beetle (Dendroctonus engelmanni Hopk.) (22). Heavy blowdown in 1939 on the White River Plateau in Colorado resulted in an epidemic infestation that destroyed 5 billion board-feet of spruce before being controlled in 1952. Engelmann spruce is attacked by other insects, but only one, the defoliating spruce budworm (Choristoneura fumiferana Clem.) is potentially dangerous.

The most common diseases are caused by wood-rotting fungi: red ring rot (Fomes pini (Thore) Lloyd), red root and butt rot (Polyporus circinatus Fr.), brown trunk rot (Peniophora luna Romell), and red heartrot (Stereum sanguinolentum A. & S.)(14). Recent studies have linked brown crumbly rot (Fomes pinicola (Swartz) Eke.), brown cubical rot (Coniophora puteana (Fr.) Karst), and spruce broom rust (Peridermium coloradense (Diet.) Arth. & Kern) with windthrow (29).

Thin bark and persistence of dead lower limbs make Engelmann spruce susceptible to destruction or severe injury by fire (fig. 4). Most root and trunk rots in old-growth appear to be associated with fire injury.

RACES AND HYBRIDS

There are no recognized races or geographical varieties of Engelmann spruce (20). However, natural crosses between Engelmann and Colorado blue spruce have been observed in the central Rocky Mountains. Fairly extensive natural crossing with white spruce is believed to occur where the ranges of the two meet in western Montana and British Columbia. In that area, mature cones are exceedingly variable in size and conformation of cone scales.

PROPERTIES AND USES

Engelmann spruce is one of the lightest of the important commercial woods in the United States. It is rated low in beam and post strength and shock resistance but can be used in some construction where strength is required. Wood is soft and machines well for ordinary uses. It has good nail-holding properties, low shrinkage, and uniform color. It is relatively free from warping, glues well, and is easy to work. Lumber

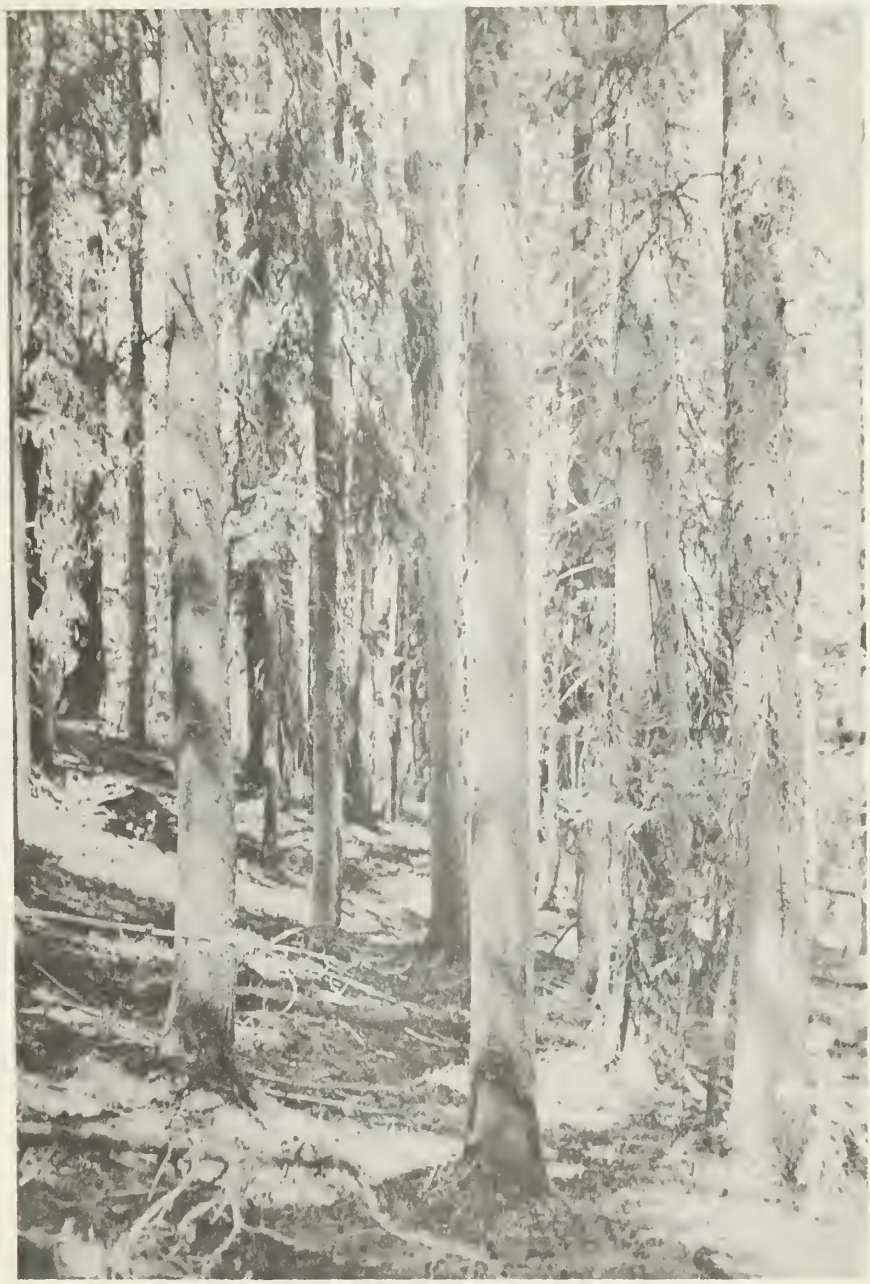

Figure 4. --Engelmann spruce does not prune well naturally. This old-growth stand still retains many dead lower branches.

can be kiln-dried or air seasoned without difficulty if sufficient time is allowed. Spruce is considered somewhat resistant to preservative treatment; however, crossties have been successfully pressure treated with creosote for many years (2).

Engelmann spruce was used principally for crossties and mine timbers in the past. Today much of the lumber is used in home construction as interior wall paneling, exterior trim, roof boards, siding, wall sheathing, shelving, subflooring, and framing. Other uses include cants for plywood manufacture, specialty items such as violins and pianos, aircraft construction, boxes, crates, and food containers (2).

Engelmann spruce has not been used much for pulp and paper, although its pulping properties are excellent. Long fibers, light color, and absence of resins permit it to be pulped readily by the sulfite, sulfate, or groundwood processes (2).

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